



**LUNDY ELECTRONICS & SYSTEMS, INC.**

Glen Head, New York 11545

(NASA-CR-115327) INERTIAL WASTE SEPARATION  
SYSTEM FOR ZERO G WMS Final Report (Lundy  
Electronics and Systems, Inc.) 9 Dec. 1971  
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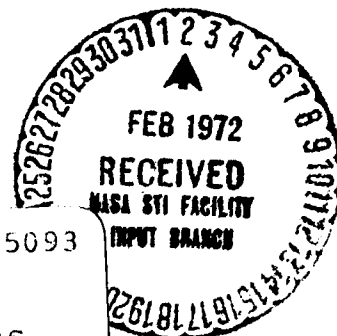
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FINAL REPORT  
FOR THE  
INERTIAL WASTE SEPARATION SYSTEM  
FOR ZERO "G" WMS

(Lundy Document No. 1506-4-R7)

prepared for

National Aeronautics and Space Administration  
Manned Spacecraft Center  
Houston, Texas 77058

under

Contract No. NAS9-11268

by

Lundy Electronics & Systems, Inc.  
Glen Head, New York 15545

9 December 1971

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**Details of illustrations in  
this document may be better  
studied on microfiche**

THE ABOVE ILLUSTRATIONS ARE NOT INCLUDED  
IN THIS DOCUMENT.

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## FOREWORD

This final report has been prepared for the NASA Manned Spacecraft Center in accordance with contract No. NAS9-11268.

As the remaining contract item, it represents fulfillment of this R&D contract.

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## I. DESIGN DESCRIPTION

The unit is configured as illustrated in the photographs and drawings included as part of this report. The uppermost portion is an aluminum seat. This seat has been configured to give the user tactile centering cues when sitting. These centering cues are exaggerated to compensate for zero gravity conditions. The seat is suspended on four shafts with coil springs as illustrated. It is free to ride up and down (bounce) according to the requirements of the user. The shafts run through lineal ball bearings to reduce friction.

Attached to the seat and mounted by means of a coil spring which fits into a flange, is the clear collection bag. This bag is made of heat sealed Aclar. Beneath the seat is a scissor-like closure activated by a solenoid. The scissors are normally open; when the solenoid is activated, they close. These scissors constitute the anti-rebound mechanism. Two handles are provided to balance the user and to provide firm grips to activate the bounce mechanism. The user "lifts" these handles to bounce down. At the end of both handles are button switches both of which must be depressed to activate the solenoid and close the anti-rebound scissors. Two windows are provided in the main body of the frame to permit documentation photography.

In the lowest part of the frame a rotary down-draft fan is connected to a cartridge filled with permanganate deodorizer pellets. The air supply is drawn from two openings in the seat flange, through connecting tubing, through the deodorizing bed, and out through the large holes in the bottom of the frame. Behind the unit is the electrical junction box which contains the power switch, wire distribution for the fan motor, switches and solenoid; and fuses. The lowest portion of the unit is a flange with holes drilled to interface with the mounting points on the test aircraft.

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Extending from the electrical box are two lengths of wire, one for 28V DC to operate the solenoid system, the second to connect into 117V 400 Hz power to operate the fan. Both wires have appropriate military type terminals to interface with the aircraft power supply.

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## II. METHOD OF OPERATION

The initial step is to mount the bag in place under the seat flange. This is done by releasing the coil spring, slipping the bag over the flange, and tightening the spring around the bag connecting the end of the spring onto a post. The flange is grooved to accept the spring and tightly secure the bag. The operator sits on the seat and at the appropriate time sharply pulls himself down by lifting up on the handles. Upon striking the bottom both switch buttons in the ends of the handle are depressed closing the anti-rebound mechanism.

Odor control is accomplished through the downdraft fan which is operating continuously. When filled, the bag is removed by releasing the spring. It is slipped off the flange, the neck is folded and sealed with the tape attached to the bag.

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## III. LABORATORY TEST REPORT

The complete laboratory test report has been included as part of this Final Report.



LABORATORY TEST REPORT  
INERTIAL WASTE SEPARATION SYSTEM  
FOR ZERO "G" WMS

Prepared for

NASA Manned Spacecraft Center  
R&D Procurement Branch

by

Lundy Electronics & Systems, Inc.  
Glen Head, New York 11545

Under Contract No. NAS-11268

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## 1.0 SCOPE

Laboratory tests performed in January and early February 1971 at prevailing laboratory conditions (pressure, temperature and gravity).

## 2.0 OBJECTIVES

The primary objective is to prove the feasibility of the system and acquire experience prior to flight test; specifically to:

- 2.1 Try out the system with human subjects and obtain subjective evaluation.
- 2.2 Measure the separation forces which are developed.
- 2.3 Measure the time sequence of events.
- 2.4 Train subjects and develop training methods.
- 2.5 Establish methods of photographing this system.
- 2.6 Predict how the system will perform in zero "G".
- 2.7 Try out waste simulations.

## 3.0 DESCRIPTION OF TEST ARTICLE

The test article was the inertial waste separation system used in the first series of flights. It had a removable contoured seat placed on guides centered on a canister. The seat could be moved relative to the canister by the operator sitting on it and exercising force on grips. This movement is limited to 3-1/2" by stops at each end of the guides. By accelerating himself towards the stops the operator generates energy which is directed to separate a suspended mass when the motion is stopped by the seat bottoming on the canister.

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## 4.0 METHOD OF TEST

Subjects sat on the seat in a harness suspended by 1/2" Shock Cord as per Figure 1 attached.\* The springs pulled up with a force sufficient to balance the suspended weight.

During these laboratory tests, an electromagnet was placed on the subject and a material of known mass suspended from it. The current running through the magnet was adjusted to hold this material up with a known force.

A special electromagnet was wound. This magnet has a pole designed to fit a ball bearing. The magnet and ball were calibrated to determine the forces necessary to pull the ball down off the magnet as a function of current. These forces were divided by the mass of the ball to obtain calibration of acceleration vs. current (see Figure 2).

A crystal accelerometer was attached to the seat and its output recorded on an oscilloscope. A magnetic proximity probe was set to trigger the scope when the seat was at a set position relative to the canister. Use of a DC (strain gauge) accelerometer was considered but eliminated as unnecessary as the crystal showed little indication of significant low frequency response. The output of the manual switch which activates the entrapment mechanism was also recorded on the scope.

A plastic bag was filled with dog food and sealed. It was placed on a solid bottom with a mating hole in both. This could fit in the seat so the operator would be able to exert force on the bag when operating the system.

\*Type I, William B. Bliss, Jr.  
& Co., Inc. 425 Park Ave. S.  
New York, N. Y. 10016

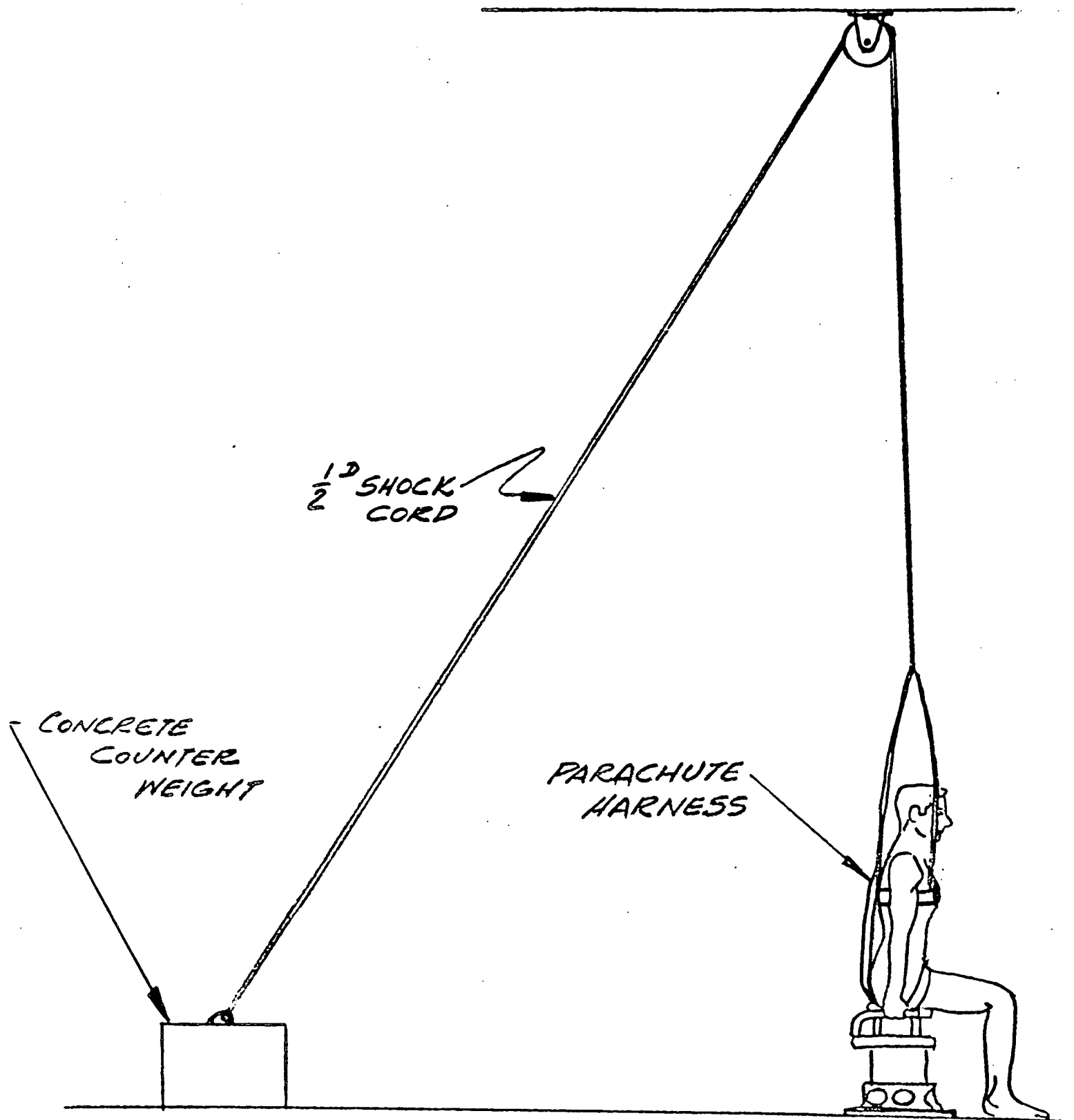
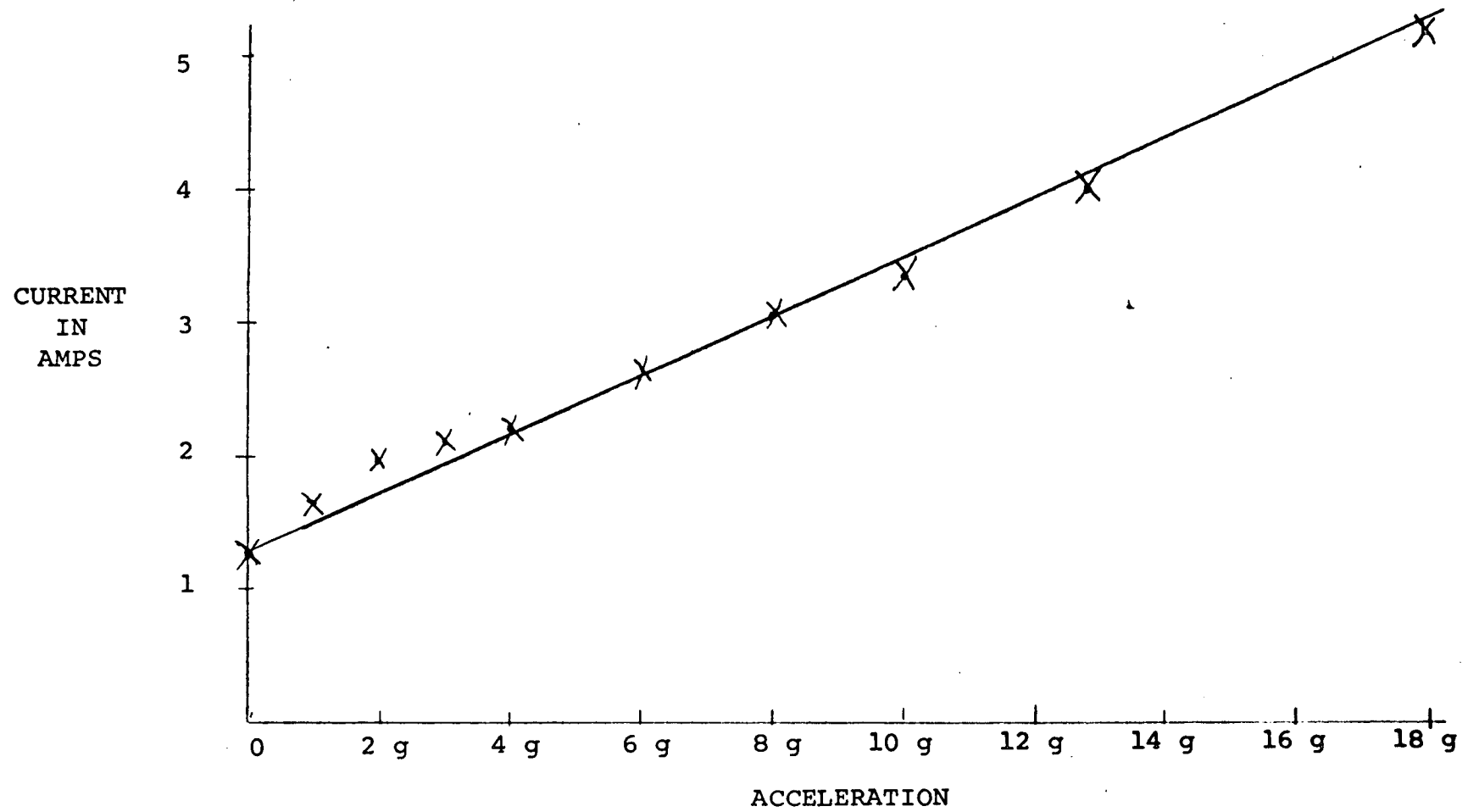


FIGURE 1 - ZERO "G" SIMULATION TEST RIG

FIGURE 2

ACCELERATION VS. CURRENT TO SEPARATE

ELECTROMAGNETIC BOLUS



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A high speed motion picture camera was used to film the subject. Two 100-ft. and one 400-ft. films were taken at 1,000 frames/second.

The two men who were to use the seat in subsequent flight test were used as operators during these laboratory tests.

### 5.0 RESULTS

The first attempts to use this device met with failure. The guide rods tended to bind preventing the seat from moving. The unit was returned to the shop and reworked.

When returned, the seat could repeatedly be made to bottom. Results with the electromagnet revealed that forces in excess of 18 g were being generated. High speed movies were taken of this phase and when developed revealed that the operator's timing was critical. It was also learned that it was possible to shift the plane of the seat by not directing the forces along the axis of the canister. This undesirable feature was eliminated before the second flight test.

When the two operators became proficient enough to release the ball on each down stroke, a crystal accelerometer was attached to the seat. Oscillograph traces revealed that forces in excess of 30 g were generated when the chair bottomed. The maximum force was a spike approximately 1 ms wide at 50% of maximum with the total energy transfer occurring over less than 10 ms. In the test plan (Lundy Document 1506-3-R5) a 2 g force and 25 ms duration was anticipated from calculations. Further practice sessions were carried on to maximize the separation force and minimize forces occurring on the rebound.

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## 6.0 CONCLUSIONS

This unit was deemed ready to be flight tested and the operators sufficiently trained to obtain further evaluation of the system. Data generated on this test will be applied to any further design and/or modifications. The setup will be invaluable in evaluating any future designs and training other operators.

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## IV. INITIAL FLIGHT TEST PROGRAM

The initial flight test program of the prototype unit was designed primarily for simulation and training, to develop operator techniques, and to discover deficiencies in the mechanism for subsequent improvements. In order to allow maximum training time on the initial flights, a simulated waste was used. Once the test subjects familiarized themselves with the operation of the unit, a training period would form the basis for actual weightless use of the inertial separation toilet with human waste.

The simulated waste consisted entirely of canned dog food (Ken-L-Ration). This material was put in a clear plastic pillow-shaped bag. A one inch diameter hole was cut in the center of the bag and the material was extruded through this hole by the subject sitting on the bag. During weightlessness extrusion was accomplished by manual pulling up of the seat. The material forced out of the bag was bounced with the seat as training in the technique for achieving maximum separation velocity. The anti-rebound mechanism was simultaneously manipulated through the use of triggers at the end of the handle bars. Both triggers had to be depressed to close the solenoid and anti-rebound mechanism arms.

In the course of the flight test a mechanical problem impaired the efficiency of the unit. The problem on the first flight test was hang-up or jamming of the rebound mechanism supports. These supports moved axially through plain bearings which jammed if the seat was canted. Each one of the four supports was independently suspended, and slight misalignment caused jamming. This design deficiency prevented efficient utilization of the bounce principle.

Lubrication of the bearings allowed completion of the flight test. Redesign was necessary to eliminate this problem during future flights.



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A second problem encountered was that of insufficient pull from the anti-rebound solenoid. A pull of 5 lbs. did not effectively operate the scissor closure mechanism and a 10 lb. pull solenoid was required.

During the first test program, the test operator had a tendency to bounce several times going up and down in rapid succession. This did not allow settling of the waste. It was determined that a single hard bounce, holding oneself in the bottom position for several seconds would both separate the waste and prevent rebound. Failure to do this would cause a descending mass of simulated waste to meet the ascending bag. This could bounce it right back up. The anti-rebound mechanism was not helpful in preventing this action since the operator had no way of determining what was happening in the unit under him. To improve operator control of the prototype unit and rebound prevention mechanism, it was recommended that a mirror be installed to enable test subject observation of the action.

Analysis of the photographs taken on the first flight documented the above observations. There was sufficient delay between the first flight and subsequent flights to remedy design deficiencies, and a newly designed unit was built for the subsequent flight test program. In addition, there were training changes and the simulated waste material was changed. Observation of the flight photographs indicated that the canned dog food was too dry and neither tacky nor viscous enough to adequately simulate low bulk diet human wastes. This dog food was therefore mixed with 1/3 part (by volume) of creamy style peanut butter to form a more tacky viscous material.

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## V. SECOND FLIGHT TEST PROGRAM

The second flight test program, following the first by several months, took advantage of the interim for re-engineering the prototype unit. Changes were as follows:

1. The plain axial bearings were replaced by lineal ball bearings and the supports by casehardened rods. This improved the suspension system. In addition, a plate was prepared which locked the four supports together to prevent canting. Thus, the plane of the seat was always perpendicular to its motion, tipping and bearing stresses were prevented, and jamming eliminated. The bounce motion was very smooth enabling maximum utilization of the inertial principle. Four small springs were added to reduce shock when the seat reached the uppermost position. A mirror was added to enable the user to observe the action of the unit.

Improvements were made to the bag attachment system. The 5-lb. solenoid was replaced by a 10-lb. solenoid. The bags were changed in design, eliminating the opaque sealing systems in the upper part to facilitate photography. The bounce technique was changed from multiple bouncing to a single hard stop bounce.

### Flight Test Report

On the first day of flight testing utilizing the single hard stop technique, it was found that the anti-rebound mechanism was not necessary. If the unit were operated correctly, the material was projected to the bottom of the bag with sufficient force to preclude rebounding, the wedge-shaped bottom of the bag and material adhesion preventing rebound. For the balance of the flight test the rebound mechanism was neither used nor needed.

During the first test day it was found that the simulated material contained in the pillow-like supply

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bag had considerable mechanical strength. When the seat was bounced to the bottom stop position, it had no tendency to fracture and break away. This was because in the bottom stop position the shock and induced g's caused the weight of the test subject to extrude additional material thus cushioning the shock on material previously extruded. This buffering effect compromised the simulation. Under normal conditions sphincter action portions the waste and a continuous extruded "rope" is not produced. To remedy this problem, fixed limited quantities of simulated material were located above the orifice. Lacking additional material, the simulated bolus broke away and descended to the bottom of the bag. Before this problem was corrected, test results were mostly unsatisfactory. Once discrete quantities were extruded, simulation test results were uniformly excellent. Thus, the first day of flight testing produced unsatisfactory films but resulted in improvement of the simulation.

The second day of flight testing produced good results with simulated materials. The third day of flight testing was limited to a single usage of the unit with actual waste. This human waste was separated and collected and the last test was successful. Analysis of motion pictures shows that the bolus was detached and very rapidly ejected to the bottom of the bag. There was no rebound. Unfortunately, due to a problem with the camera the successful period of testing has been documented poorly. The films are very dark. Under proper projection conditions, however, utilizing a completely darkened room, very bright projector bulb and working close to the screen, the trajectory of the waste material both simulated and real, can be observed. Fortunately the last test, utilizing real material, may be clearly seen.

During the test period when actual wastes were used odor control seemed to work. The mirror was useful. The anti-rebound mechanism was neither used nor needed. The major problem was mechanical attachment of the bags; replacing the bags was difficult. A more rapid and positive bag changing system is required.

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A problem that had been predicted, namely that the waste material would become attached to the person during the rebounding action did not occur. Efficient use of the unit requires a short period of training but skill in operating the system is easily acquired. The use of simulated material is recommended for training.

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## VI. CONCLUSIONS AND RECOMMENDATIONS

The conclusions documented on the films demonstrate the feasibility of bounce separation. Design changes will be necessary to enhance the effectiveness of the unit and convert it from a feasibility test unit to prototype flight hardware.

These changes include a mirror for guidance of the user. The anti-rebound mechanism can be eliminated as unnecessary. The bounce cycle should be better controlled with dash pots or other energy absorbing systems. Open flange toe clips would improve the user's balance and should be added. A rapid magazine type bag changing system, preferably with sealing capability would enhance the convenience of this unit. The odor control system should be retained but redesigned to be compatible with the redesign bag changing system.



Photo No. 1  
Zero "G"  
Inertial Separation Subsystem  
(Front View)

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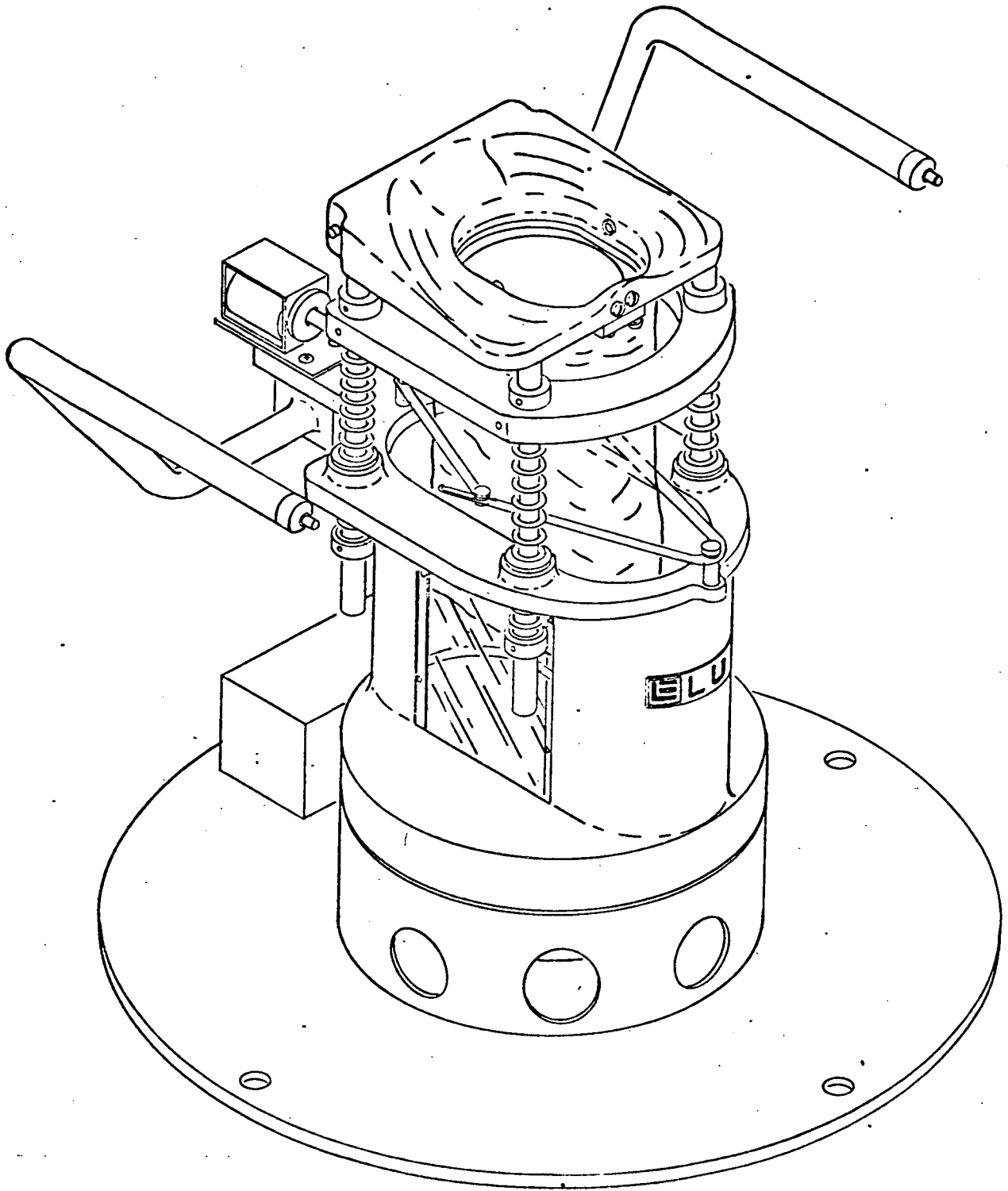


Photo No. 2